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CAR TRANSFER ADAPTIVE SYSTEM FOR DISABLED

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Abstract: *For a normal life, persons with locomotors disabilities need mobility. Their transfer from bed to wheel chair and then into a car represents one of their essential needs. This paper presents research results on the adaptive mechatronic system for transferring people with locomotor disabilities from the wheelchair into the car. Experiments with perception subsystem have been conducted in real motion environment. The mechatronic system's main component is a parallelogram mechanism whose motion is controlled by the processed signals acquired from the sensors of visual perception subsystem. For avoiding person's body collision with different parts of the car (pillar, celling, door) the perception subsystem has camera and laser sensor. The information from these sensors determine accurate control of parallelogram mechanism motion.*

Keywords: *Mechatronic System, Artificial Intelligence, Visual Perception Subsystem, Hybrid Control, Locomotor Disability.*

1. INTRODUCTION

A healthy people is a real force for society and for humanity. When human health is affected, we have a duty to provide support by all means. Through mixed teams of doctors, engineers, researchers and other professionals, solutions are developed so that AAL (Ambient Assisted Living) becomes a normal one. The study, analysis and work in this team formula are given by the motivation of the help for people with locomotion disabilities, but also to inspire as many people as possible. Whether they have stability problems or hip or knee joints or are in medical recovery after surgery or cannot move their legs, people need mobility, being in bed is totally harmful to their health. To get from bed to the kitchen table or to the personal car (normal size, European size) a person with locomotion disabilities relies on a wheelchair. The next step, namely the transfer from the wheelchair to the car is a mandatory activity, cumbersome, usually uncomfortable. The proposed smart adaptive system meets the needs of people with locomotion disabilities to make the transfer from the wheelchair to the car.

The development of intelligent concepts at macro and micro level is in full swing around the world in order to meet all the needs in all areas of activity. The need for robots in the community of people with social and medical problems is certain and proven experimentally. The researchers present in [1] a sustainable version of an integrated intelligent system that is based mainly on control, but also on resources such as information, sensors, databases and technologically advanced equipment. In addition to the above mentioned, the cooperation of robotic systems such as anthropomorphic stepping robots with virtual platforms is mandatory to provide personalized services in order to improve the mobility and the quality of the human life. The smart community system is a concept that is evolving day by day, both theoretically and practically. Today, the lives of the elderly or people with various diseases cannot be imagined without the internet and without collaboration with the SARs (Socially Assistive Robots). The elderly independently living at home, helped by robots in AAL is studied in [2]. The difficulties of people living alone are recorded, monitored and solved through a platform with specific advanced functions integrated in the social robot. The results clearly show that the solution is feasible, and the long-term acceptability of social assistance robots for the elderly is an undeniable success. Social work robots are very helpful for the elderly and people with reduced mobility. Whether on wheels or on their feet, these companions are real socio-psychological companions. The research [3] proposes a cheap stepping robot, equipped with a 3D visual perception subsystem that defines its own position and orientation in the environment, while adjusting its motion according to the patient's possibilities of movement, providing assistance and protection. The control subsystem has a strong anti-balance module. The special capabilities recommend it as a good, non-contact guide for users.

The design and development of robotic equipment and systems for the purpose of helping the elderly, visually impaired, people with locomotion disease or those in medical recovery is a priority for researchers all around the world. Assistance through specialized intelligent systems related to increase walking mobility is analyzed in terms of mechatronic solutions in [4]. The achievements of the last year's show that there are numerous mechanical structures and models of robotic systems with advanced control that are extremely efficient, improving the health of the users in a considerably short time. The best performing robotic systems for improving walking for people with disabilities are those that include perception and navigation subsystems, despite the high price. A mixed technical solution for the individual medical rehabilitation at home for people with locomotion disabilities is the wheelchair-exoskeleton system [5]. The control of the system is hierarchical and has a first level based on the voice recognition interface of the task, the second level that decides the possible actions, and the third level which transmits the decisions of execution and coordination of the movements. The proposed control subsystem is a high-performance one, based on ADRC (Active Disturbance Rejection Control) strategy and PID (Proportional-Integral-Derivative) control in a disturbed environment. The experimental validation results in the real environment show the efficiency and robustness of the home robotic system that tracks through the sensors the precise positioning in relation to the exoskeleton.

Wheelchairs are particularly useful devices for the elderly or for the people with limited mobility, both indoors and outdoors. The authors [6] designed and tested a modular, multifunctional mechatronic structure with multiple possibilities for the patient's back and leg posture, which has an adjustable seat height and also overcomes the stage-type obstacles encountered on the route. The control subsystem attached to this robot includes a joystick interface for seat control and a remote control for performing functions. Experiments performed in the real environment with the prototype of the chair have shown that it maintains its stability during the ascent and descent of the steps, and the position of the various postures offers a good comfort to the patient. The movement in narrow spaces of the people with locomotion disabilities by means of a robotic system is investigated in [7]. The patient's assisted walking strategy is controlled by admittance control and sensors, through commands given to the human-robot interaction subsystem that ensures safe position, orientation and navigation. The results are validated in the virtual environment and experienced in the real environment, so that through non-verbal communication and haptic feedback the navigation to the destination and the avoidance of obstacles are guaranteed.

The parameters of the physical transfer processes in which people with medical conditions are involved are carefully monitored. The experiments performed in [8] show the qualitative and quantitative importance of the speed of ascent and descent of the patient in an elevator-type robotic device. The study performed for different speed values took into account the patient's weight and transfer time, as well as the patient's state parameters, respectively HR (Heart Rate) and EMG (ElectroMyoGraphy). The conclusions show that the necessary medical care for the patient is performed in a longer time than the manual transfer, but with minimal discomfort for the patient and with little effort for the medical staff.

Recovering of the patients with neurological disorders is an extremely complex and delicate activity that requires also their mental effort. In order to support them, in addition to the medical treatment and counseling, researchers [9] designed and prototyped an useful chair for rehabilitation programs, as a training support, for those who had a stroke. The assistance provided by the therapist through the proposed chair helps control the condition of the torso and legs by producing an electromagnetically induced electric field in them, similar to the stimuli of effort. The chair was well received and with good results by the patients.

The training of medical staff to assist the patients is a complex and time-consuming process. The authors [10] designed and developed a humanoid robot to be used to train nurses for the case of transferring the patient with mobility problems from the hospital bed to a wheelchair. The nurses interact physically and vocally with the prototype robot exercising to improve their skills. The performance of the robot is validated experimentally, reactions controlled by the movement of the limbs.

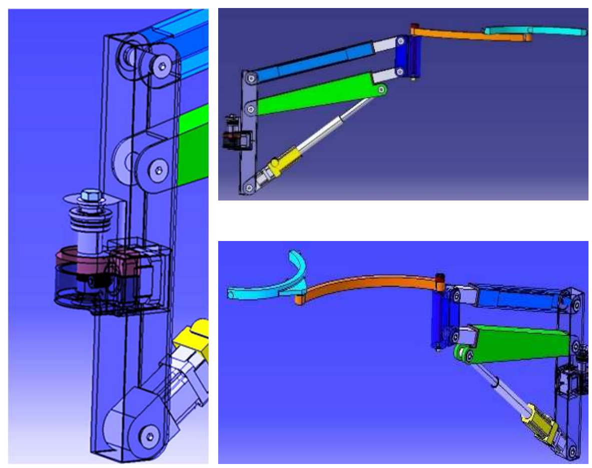
People's locomotor disabilities caused frequently by accidents require therapy to increase mobility by means of medical recovery robots. The research [11] includes the structural-mechatronics conception and the design of an elevator type system. Based on the articulated mechanism of the parallelogram, the kinematic analysis was performed so that the transfer of the person from the wheelchair into the car to be feasible. Further development of the research, by improving the system concept so that to enable more degrees of freedom and to adapt for fitting different car types – is presented in this paper. In order to avoid the collision of people’s body with car parts, an object detection subsystem has been designed.

The article is further structured as follows. Section 2 describes the concept, materials and methods used, respectively the original mechanical structure designed and the configuration of the visual perception subsystem. Section 3 details the tests and results of the simulation in virtual environment and of the experimentation in real environment, the control method when the patient is assisted transferred into the car. Section 4 concludes the paper by presenting the achievements of this research and its further development.

2. MATERIALS AND METHODS

The concept of car transfer system is a modular one, made of different subsystems that are: parallelogram mechatronic system, visually perception, command and control system.

The mechatronic system, named ADAPT-CAR, (see figure 1) is based on a parallelogram mechanism (mechanical structure) with two actuators (stepper motors) and worm gear transmission for motions. It has been designed to support a 150 kg weight person, its structure is made of duralumin alloy of about 1.8 kg. This mechatronic system is placed and, further, removed manually - once the person is installed on the front seat.



a. stepper motor

b. parallelogram mechanism and mechanical structures

Fig. 1. Mechatronic system basic structure

Fig. 2. Car fixing adaptive subassembly

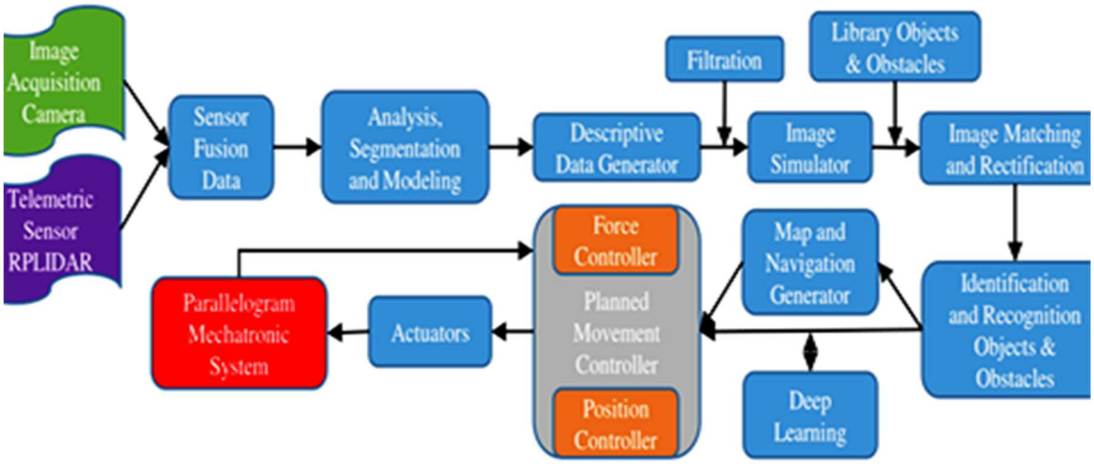


Fig. 3. Diagram of the adaptive transfer system method

There is also an adjustable component subassembly for fixing the ADAPT-CAR on different types of car (frames and pillars), without the need of any changes or intrusion into the car structure (see figure 2).

The proposed method for adaptive transfer system is shown in figure 3. The visual percussion subsystem of the designed parallelogram mechatronic adaptive system consists of the following:

- Sony's HQ Raspberry Pi camera with retro backlit sensor model IMX477R used for both photos and videos. Features and technical specifications include: 12.3 MP resolution that provides an excellent image of applications through 4056 (H) x 3040 (V); high sensitivity in low light conditions; adjustable focus on the back; diagonal sensor 7.9 mm; possibility to mount type C and CS objectives (https://www.amazon.com/Waveshare-Raspberry-Pi-Camera-Sensitivity/dp/B088NH3ZS5).
- CS-Mount 6 mm Wide Angle Lens from Raspberry Pi. Features and technical specifications include: image format 1/2"; focal length 6 mm; view angle 63°; back focus 7.53 mm (https://www.amazon.com/Waveshare-Raspberry-Pi-Camera-Sensitivity/dp/B088NH3ZS5).
- Laser sensor model RPLIDAR A3. Features and technical specifications include: sampling rate of 16,000 rpm due to advanced embedded technology and brushless motor; used to quickly and accurately create the robot environment contour map; the maximum radius of information collection of 25 meters both indoors and outdoors; stability in identifying black and white objects; good reliability in natural daylight; reduced noise (https://www.slamtec.com/en/Lidar/A3).
- NVIDIA Jetson Nano Developer Kit model P3449_B01 used for image and object identification and recognition applications. Features and technical specifications include: 128-Core NVIDIA Maxwell GPU; Quad-Core ARM A57 @ 1.43 GHz; 4 GB 64-bit LPDDR4 25.6 GB/s; 10/100/1000 BASE-T Ethernet; micro SD Slot; HDMI Port; USB 3.0 / 2.0 (https://cdn.sparkfun.com/assets/0/7/f/9/d/jetson-nano-devkit-datasheet-updates-us-v3.pdf).

The performance of the device is based first on the visual perception subsystem and then on the hybrid force-position control method.

The precise trajectory, determined by the patient's safety, is due to planning in correlation with the driving forces / torques of the actuators. The proposed solution benefits from proportional damping at the end of the motion, being efficient in a rigid environment and offering robustness to the control scheme in confusing modeling conditions of a narrow workspace.

Patient safety is guaranteed by the speed values of the final effector (which is related to the values of reaction forces / torques) and by the accurate estimation of the space available for getting the person into the car.

Achieving the proposed goal is done through the strategy adopted according to which the control of the position of the final effector is a priority over the control of the force. Unwanted collision (contact) are thus avoided against the background of accepted deviations of forces / couples.

3. EXPERIMENTS AND RESULTS

Moving from the food-filled trunk to the right front door is done with the wheelchair, and then the designed device is installed.

The paper includes two application parts, as follows:

- in the virtual environment, when the designed mechanical structure type parallelogram is fixed on the car pillar and the locomotor disabled person is transferred onto the passenger seat.
- in real environment, with the visual perception subsystem installed on the robotic platform frame (see figure 4).

3.1 Transfer Adaptive System

The device is designed to be used both for boarding on and unboarding off the car.

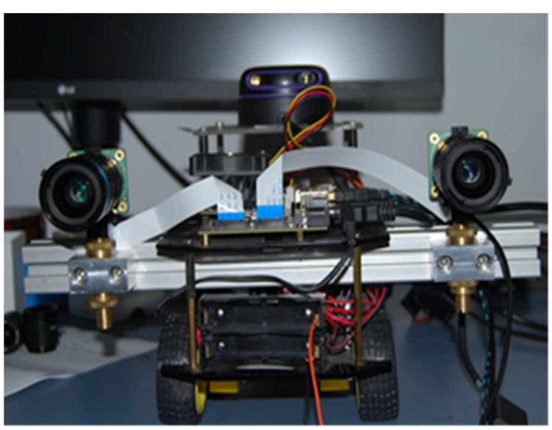


Fig. 4. Mobile mechatronic system

Fig. 5. Fixed ADAPT-CAR mechatronic system

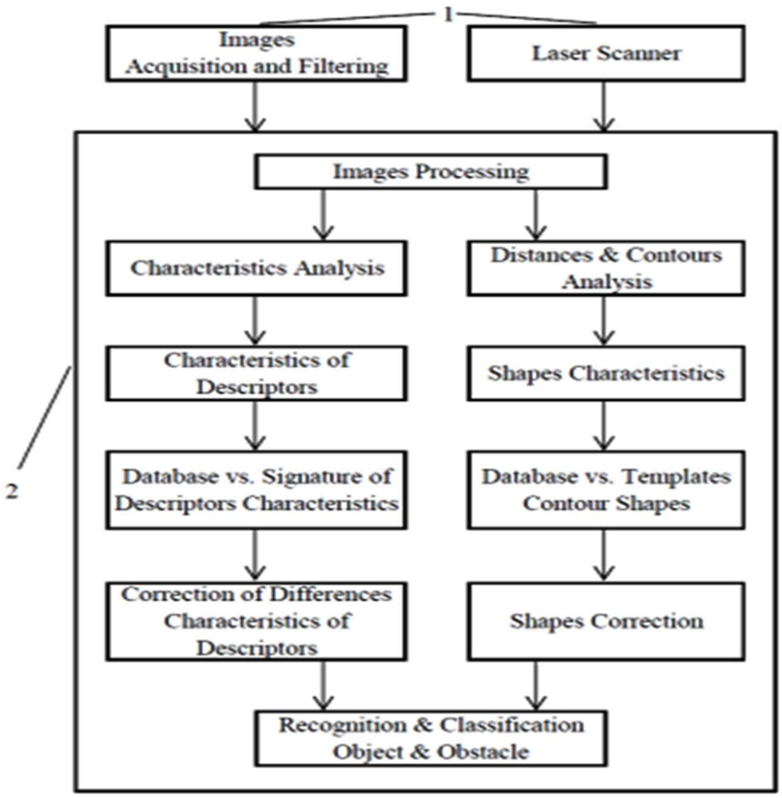
The proposed system has been designed to meet the following requirements: mechanical strength and stability from a constructive point of view, constructive adaptability for different car types, ease of installation and disassembly, safety and accessibility in operation, low energy consumption, easy operation for people up to 150 kg, simple maintenance and financially affordable.

The mechatronic structure designed and presented in this article is developed with CATIA V5 multiplatform software, being made after a series of successive modifications that offer mechanical strength and stability to the ADAPT-CAR product (see figure 5).

3.2 Operational Test of the Perception Subsystem

Getting in and out of the car is a challenging action for a person with locomotor disabilities. This is why the designed car transfer adaptive system assists in determining car pillar position, door frame space as well as other possible obstacles on motion track, in terms of visual information. Measurements of the RPLIDAR A3 laser sensor and the images captured by the Raspberry Pi HQ IMX477 camera are transformed into information that further supports the control subsystem (see figure 6).

Experiments in the real environment with the visual perception subsystem have assimilated the car door with the door of a room. The process of identification and recognition of objects / obstacles (based on the two modules, hardware and software) proved to be accurate and fast respondent. Examples of the obtained results are shown in figure 7 and figure 8.



Legend:
1 – hardware module;
2 – software module

Fig. 6. The architecture of object identification and recognition process

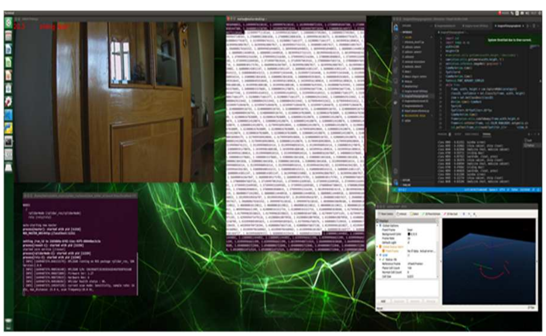


Fig. 7. Door screenshot with 6mm fisheye lens, GoogLeNet database

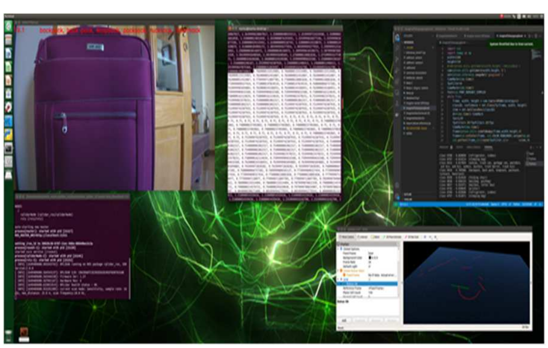


Fig. 8. Obstacle screenshot with 6mm fisheye lens, GoogLeNet database

These two figures show the images of the real situation in which the door first appears and then an obstacle appears in the door frame. The proposed subsystem correctly identifies the door and the obstacle based on the captured image, as well as the distance at which they are positioned. The proposed visual perception system, with LIDAR sensor, partially encompasses the work environment map.

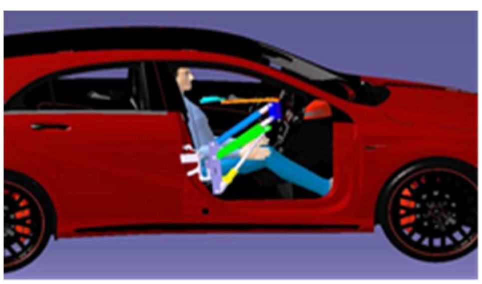
The results of the experiments performed in the real environment with the proposed visual perception subsystem indicate a good accuracy of the object recognition process in a short time, of 553 ms in the case of the door and of 705 ms in the case of the obstacle.

Based on the results from object recognition and detection, exemplified in above, there has been carried on simulation of the mechatronic system motions, so that to accomplish the objective, that is transfer the person with locomotor disability onto the front car seat (see figure 9).

Based on the results from object recognition and detection, exemplified in above, there has been carried on simulation of the mechatronic system motions, so that to accomplish the objective, that is transfer the person with locomotor disability onto the front car seat (see figure 9).

a. phase 1: getting the person from the wheelchair

b. phase 2: transferring the person toward the front seat



c. phase 3: person on the front seat

Fig. 9. Phases of person transfer by ADAPT-CAR system (a; b; c)

4. DISCUSSION AND CONCLUSIONS

For a person with locomotor disabilities who uses a wheelchair there arise some hard problems and concerns. How do I get in the car on the front seat, and how does the proposed device work?

The social assistance robotic system used for the transfer of people with limited mobility on the front car seat is designed to be a compact and robust product, adjustable, safe and easy to use. The system works by a simple push of a button, after placing the person in the device, and in a short time the transfer to the seat next to the driver is done smoothly. The operation is simple and extremely practical.

The parallelogram mechatronic system provides power, controlled assistance and safety when transferring people.

The constrained movements resulting from the constraints imposed by the environment (care and door frames) are controlled stably and precisely by the trajectories of the position in real time and by force.

In the future we aim to develop new strategies to control the motions of the system, to optimize the transfer of the person into the car, to attach sensors for monitoring heart rate and patient electromyography, to include voice communication and to experiment the prototype on a wide range of body models and car types.

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SISTEM ADAPTATIV DE TRANSFER IN AUTOTURISME PENTRU PERSOANE CU DIZABILITATI

Rezumat: Pentru o viață normală, persoanele cu dizabilități locomotorii au nevoie de mobilitate. Transferul lor din pat în scaunul cu rotile și apoi în mașină reprezintă una dintre nevoile lor esențiale. Această lucrare prezintă rezultatele cercetării privind sistem mecatronic adaptiv pentru transferul persoanelor cu dizabilități locomotorii din scaunul cu rotile în mașină. Experimentele cu subsistemul de percepție au fost efectuate în mediul de mișcare reală. Componenta principală a sistemului mecatronic este un mecanism paralelogram a cărui mișcare este controlată de semnalele procesate primite de la senzorii subsistemului de percepție vizuală. Pentru evitarea coliziunii corpului persoanei cu diferite părți ale mașinii (stâlp, tavan, ușă), subsistemul de percepție are cameră și senzor laser. Informațiile de la acești senzori determină controlul precis al mișcării mecanismului paralelogram.

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